

CENSUSES AND BREEDING OBSERVATIONS OF THE BIRDS ON KOHALA MOUNTAIN, HAWAII

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The Kohala Mountain Forest remains one of the least known areas in the Hawaiian archipelago. A wide variety of avian species was found there during the late 1800's (Wilson and Evans 1890-1899, Rothschild 1893-1900). Palmer (p. 58 in Rothschild 1893-1900) collected one of the few specimens of the Ula-ai-hawane (*Ciridops anna*) and Perkins (1901) reported this forest to be one of the last strongholds of the Ou (*Psittirostra psittacea*) on Hawaii. Since 1900 there has been little ornithological work done in this region; Pratt (1967) recorded five native bird species in the southernmost part of the forest, but Donaghho (1971) failed to find any native birds in an expedition along the northern slope of the mountain. Berger (1975) and van Riper (1973, 1974, 1976, 1978a) reported on open-habitat birds, most of which were introduced species.

Because so little suitable habitat remains in the islands for Hawaii's endemic birds, it is imperative to document extant forest areas which contain threatened or endangered species. From 1969-1972 I conducted censuses and recorded the breeding behavior of birds in Kohala Mountain Forest, attempting to (1) define composition of the present avifauna, (2) measure uniformity of species composition throughout the forest, (3) quantify relative population numbers of each species, and (4) delimit aspects of the breeding seasons.

METHODS

Study area.—The Kohala Mountain Forest is a mesic ecosystem with a mixed canopy of 'ōhi'a (*Metrosideros collina*) and 'ōlapa (*Cheirodendron trigynum*) trees, underlain by tree ferns (*Cibotium* spp.) and other subcanopy tree species of which *Pelea* ssp. are the most common. The vegetation of this area is most similar to that of East and West Maui, being different from any other forest on the island of Hawaii (Rock 1913). The paucity of fieldwork in this area has been largely due to the rugged terrain. The forest is bounded on two sides by the precipitous canyons of Honokane on the west and Waipio Valley on the east, and by sheer sea cliffs to the north. Only limited access is available from the south through private ranch lands.

The principal study area was a 0.25-km² quadrat at 1100 m elev. between Puu Laelae and Kohakohau Gulch (Fig. 1). Comparative census locations were the Kehena Ditch Trail, Eke, and Kawainui Stream area. In pasture areas surrounding the forest, numerous incidental sightings were noted.

Techniques.—Breeding observations were made throughout the 3 years of the study. During 1971 and 1972, 222 h were spent censusing during 47 daily-count periods. I made most observations during the peak breeding season (February to May); however, censuses were also undertaken in an early, late, and a nonbreeding period (January, July, and November).

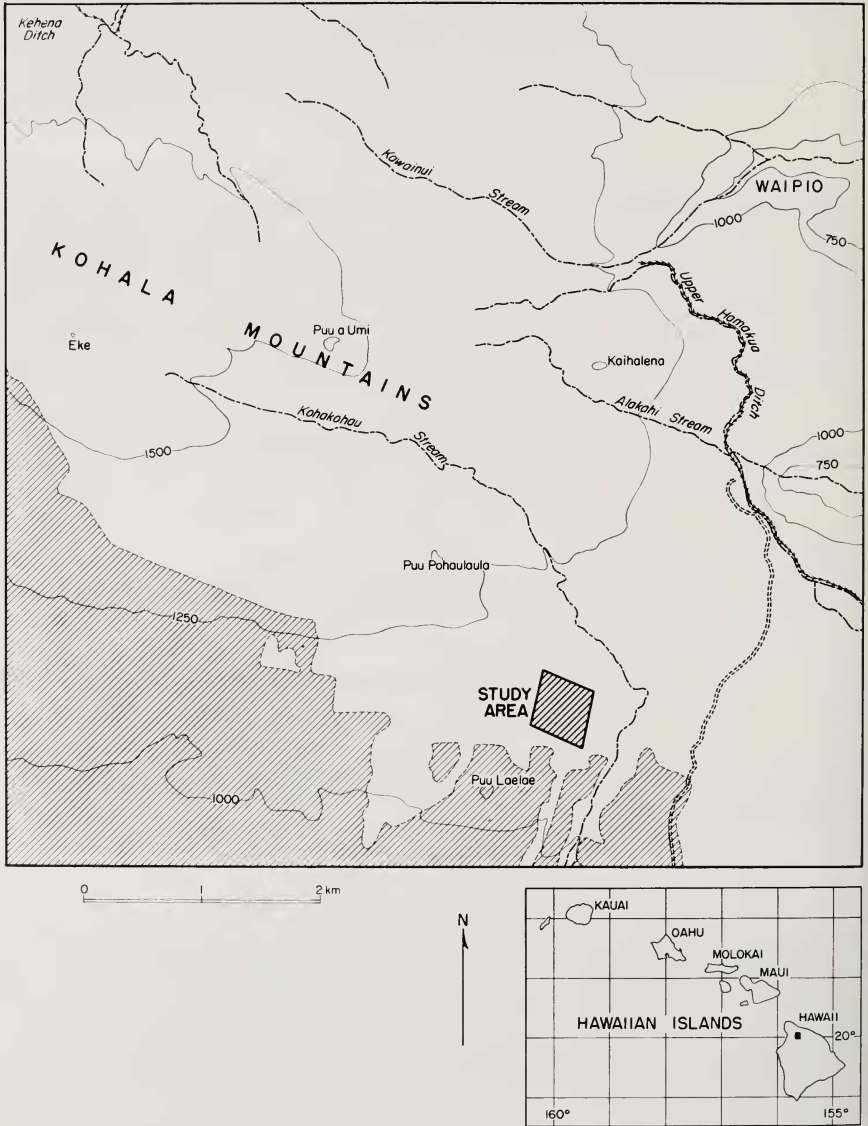


FIG. 1. Map of a portion of Kohala Mountain, Hawaii, showing the study area (dark hashing) and locations where comparative censuses were conducted. Elevation contours are in meters, double dashed lines are jeep roads, and light hashing denotes pasture land adjacent to the forest.

respectively). Strip transect counts were conducted (Emlen 1971); however, unlike Emlen's technique, the perpendicular distance of the bird from the observer's path of travel was not recorded.

A total of 38 daily counts was made in the principal study area in which 178 h were spent censusing. The counts were from 07:00 through 12:00 and conducted at a slow uninterrupted pace. Count periods averaged 4.7 h, but were of unequal length because of variable weather conditions. All birds were recorded as either an aural or visual detection, and age and sex were noted whenever possible. In order to minimize double registrations, the time, location, and direction of flight were recorded. No "squeaking" or other sounds were used to lure birds.

On alternate months during the peak breeding season, comparative counts were conducted in habitat of the Kohala Mountain Forest which was similar to that of the principal study area. A total of 44 h was spent during 9 days of comparative censusing, three each at the Kehena Ditch, Eke, and Kawaiui Stream. These counts were conducted on the day following a census in the principal study area, under similar weather conditions, and during the same time period as the previous day's census.

The numbers of each species encountered per hour of censusing were used to describe abundance levels (Rotenberry and Wiens 1976). These data were then used to define:

$$\text{relative abundance of species } i = N_i/A$$

where N_i = total number of individuals of the i th species recorded and A = total number of the most abundant species; and

$$\text{frequency of species } i = S_i/S_t$$

where S_i = number of count periods in which the i th species was observed and S_t = total number of counts; and

$$\text{incidence of species } i = N_i/S_i.$$

All statistical analyses were computed on a Burroughs 6700 using SPSS programs (Nie et al. 1975). Where data were not normally distributed, transformations were used before application of statistical tests. The level of statistical significance was considered to be $P \leq 0.05$.

RESULTS AND DISCUSSION

Species distribution and abundance.—A total of 13 bird species was recorded during censuses in the Kohala Mountain Forest, while 16 other species were noted during incidental observations on the mountain. Native species predominated in the forest area (Table 1), while introduced species were more common in the pasture land and introduced forests at lower elevations.

Native species.—The native raptors preferred open pasture habitat to that of the closed-canopy forest. Numerous incidental sightings of the Hawaiian Hawk and the Short-eared Owl were made outside of the forest. The hawk was most frequently observed soaring over the deep valleys on the northern and northeastern edges of the forest while the owl was most common over pasture lands. Because of releases by the Hawaii Division

TABLE 1
 BIRDS RECORDED IN THE KOHALA MOUNTAIN FOREST DURING 47 COUNT PERIODS FROM
 1970-1972

Species	No. counts in which species were observed	Total birds recorded		Relative abundance	Species frequency	Species incidence
		No. aural	No. visual			
Hawaiian Duck (=koloa) (<i>Anas wyvilliana</i>)	2	—	4	0.004	0.04	2.00
Hawaiian Hawk (=’io) (<i>Buteo solitarius</i>)	2	—	2	0.002	0.04	1.00
Short-eared Owl (=pueo) (<i>Asio flammeus</i>)	2	—	2	0.002	0.04	1.00
Red-billed Leiothrix* (<i>Leiothrix lutea</i>)	34	191	23	0.230	0.72	6.29
Melodious Laughing-thrush* (<i>Garrulax canorus</i>)	1	1	—	0.001	0.02	1.00
Elepaio (<i>Chasiempis sandwichensis</i>)	44	160	172	0.360	0.94	7.55
Japanese White-eye* (<i>Zosterops japonicus</i>)	42	613	229	0.910	0.89	20.05
House Finch* (<i>Carpodacus mexicanus</i>)	6	22	11	0.040	0.13	5.50
Common Amakihi (<i>Hemignathus virens</i>)	46	421	280	0.760	0.98	15.24
Hawaii Creeper (<i>Oreomystis mana</i>)	7	1	10	0.010	0.15	1.57
Nukupuu (<i>Hemignathus lucidus</i>)	1	—	1	0.001	0.02	1.00
Apapane (<i>Himatione sanguinea</i>)	45	800	323	1.000	0.96	24.96
Iiwi (<i>Vestiaria coccinea</i>)	33	188	93	0.300	0.70	8.52

* Denotes introduced species.

of Fish and Game, the Hawaiian Duck has recently been returned to the Kohala Mountain Forest. The greatest concentration of Hawaiian Ducks is presently in the Kahua Ranch (the principal Fish and Game release site), scattered throughout the smaller cattle watering holes up to the boundary of the forest near the Kehena Ditch. One pair was observed in

the Hamakua Ditch during incidental sighting periods throughout 1971, but no young were seen.

The most frequently observed native birds during censusing were passerines, of which the endemic Drepanidinae were the most common. The Apapane and Amakihi were found throughout most of the forest whereas the Iiwi was much more localized, being found only where extensive stands of larger 'ōhi'a occurred. The endangered Hawaii Creeper was observed most often in the forest between Puu Eke and the Kehena Ditch Trail, being quite rare to absent in other areas of the forest. The Nukupuu, which heretofore has not been reported from the island of Hawaii, was observed during one count period. The single observation was made on 29 June 1971, and was of a very bright yellow male fluttering in front of and probing into the blossoms of 'ōhi'a trees. Because of the open and low stature of the forest I was able to observe this bird at close range for an extended time period. At first I believed the bird to be an Akiapolauu (*Hemignathus munroi*), but it lacked the straight, robust lower mandible characteristic of that species. Instead, the lower mandible fit into the curve of the upper portion, and was about one-half as long. The bird was also seen by G. Haines, and in the following week we compared descriptions in our field notes with specimens at the Bishop Museum in Honolulu. The bird we observed most closely resembled the Maui subspecies of the Nukupuu, in size, color, and appearance of the bill.

It is possible that the bird was a straggler from Maui. However, because of the extreme rarity of the Maui race, this origin seems unlikely. After more than 50 years of no records, the Nukupuu was "rediscovered" on Maui in 1967 (Banko 1968). Even though much fieldwork has been done on that island since then, very few additional sightings of this bird have been made (Conant 1981a).

The bird could also represent a Hawaiian population of the Nukupuu. There is in fact little basis for the assumption that the Akiapolauu replaced the Nukupuu on Hawaii, seeing that the former rarely if ever takes nectar and the latter does so quite frequently (Perkins 1903). The Kohala Mountain Forest, in age as well as species composition, is more similar to that of Maui than to any other forest of Hawaii (Rock 1913). Therefore, the Kohala Mountain Forest would be more favorable to Nukupuu occupancy than any other area on the island of Hawaii.

Introduced species.—Of the introduced species, only the Japanese White-eye and Red-billed Leiothrix were consistently found within the Kohala Mountain Forest during counts (Table 1). The House Finch preferred open, disturbed pasture over the more dense forest habitat (see also van Riper 1976). Only one Melodious Laughing-thrush (*Garrulax canorus*) was re-

TABLE 2
MONTHLY RELATIVE ABUNDANCE OF BIRD SPECIES AS DETERMINED FROM 47 COUNT PERIODS CONDUCTED FROM 1970-1972 IN THE KOHALA MOUNTAIN FOREST, HAWAII

Species	Month						
	January (172.5) ^a	February (150.5)	March (375.5)	April (79.0)	May (215.0)	July (101.0)	November (21.0)
Amakihi (701) ^b	1.00 (228) ^c	0.71 (214)	0.52 (157)	0.37 (31)	0.34 (59)	0.31 (8)	0.17 (4)
Apapane (1123)	0.75 (170)	1.00 (302)	0.53 (162)	1.00 (83)	0.96 (166)	0.65 (17)	1.00 (23)
Elepaio (332)	0.19 (44)	0.22 (66)	0.36 (109)	0.28 (23)	0.35 (60)	1.00 (26)	0.17 (4)
Iiwi (281)	0.13 (30)	0.36 (110)	0.29 (89)	0.23 (19)	0.18 (31)	0.08 (2)	— (0)
Red-billed Leiothrix (214)	0.06 (14)	0.07 (21)	0.26 (78)	0.42 (35)	0.25 (43)	0.77 (20)	0.13 (3)
Japanese White-eye (842)	0.37 (85)	0.67 (202)	1.00 (304)	0.75 (62)	1.00 (173)	0.58 (15)	— (0)

^a Numbers in parenthesis = total census hours.

^b Numbers in parenthesis = total birds counted.

^c Numbers in parenthesis = total birds counted that month.

corded during the two years of this study; but, the U.S. Fish and Wildlife Service has just completed a census of the area and has found that this species has greatly increased in numbers in the 10-year period between the two census efforts (J. M. Scott, pers. comm.).

A number of introduced species were noted on the periphery of the forest but not recorded during count periods. Nests of the Northern Cardinal (*Cardinalis cardinalis*) and Nutmeg Mannikin (*Lonchura punctulata*) were found on the forest edge, and single individuals were observed deeper in the forest. Eurasian Skylarks (*Alauda arvensis*) nested and foraged only in pastures outside of the forest. The House Sparrow (*Passer domesticus*) and Common Mynah (*Acridotheres tristis*) were found only near human habitations, while the Saffron Finch (*Sicalis flaveola*) and Warbling Silverbill (*Lonchura malabarica*) were occasionally observed at lower elevations in the introduced forests. The Rock Dove (*Columba livia*), Spotted Dove (*Streptopelia chinensis*), Zebra Dove (*Geopelia striata*), and Barn Owl (*Tyto alba*) were all recorded at elevations well below the forest boundary. Numerous game species released by the Hawaii Division of Fish and Game have become established in the pasture lands adjacent to the Kohala Mountain Forest and were recorded during incidental observations

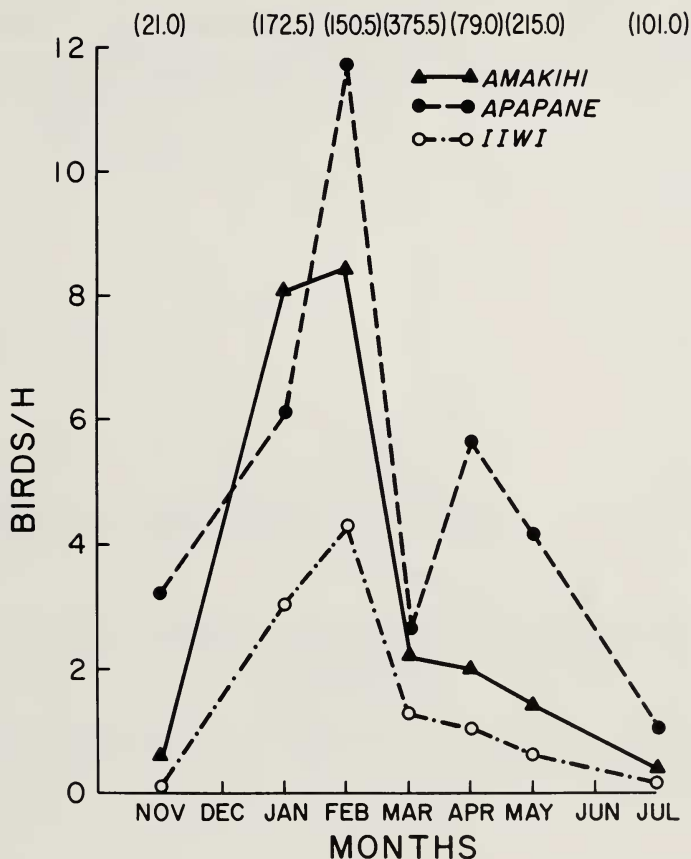


FIG. 2. Average monthly numbers of nectarivorous birds recorded during counts from 1970–1972 in the Kohala Mountain Forest, Hawaii. Numbers at the top in parentheses are sample sizes.

(e.g., Ring-necked Pheasant [*Phasianus colchicus*], Blue Pheasant [*P. versicolor*], Black Francolin [*Francolinus francolinus*] Erckel's Francolin [*F. erckelii*], Grey Francolin [*F. pondicerianus*]).

Unrecorded species.—Noticeably absent from the forest were the Hawaiian Thrush (*Phaeornis obscurus*) (see also van Riper and Scott 1979), and other less common endemics such as the Akepa (*Loxops coccineus*), Akia-polau and Ou. None of the native species which historically occurred in the forest, but are now believed to be extinct, were observed. Although I did not find evidence of breeding seabirds, Kepler et al. (1979) recently

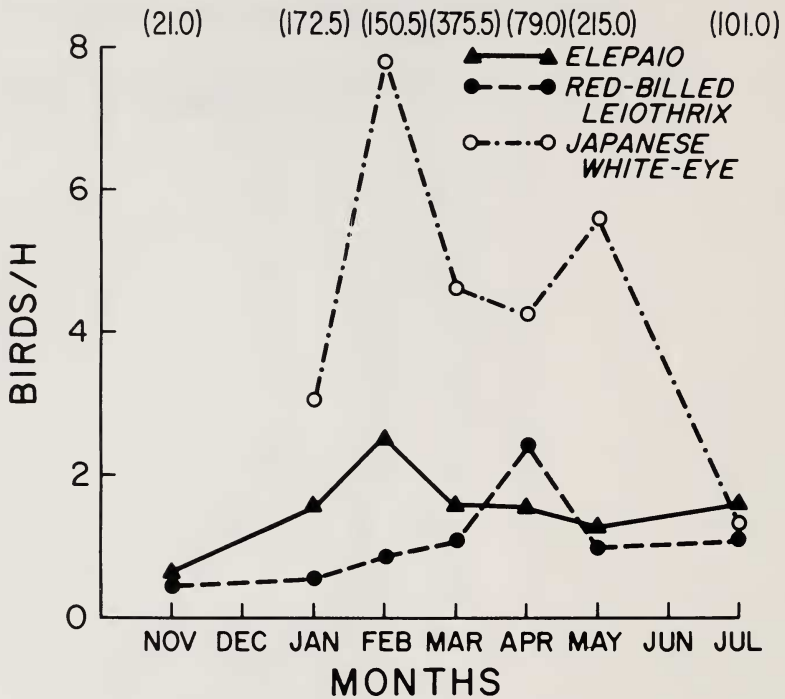


FIG. 3. Average monthly numbers of the common non-nectarivorous passerine species recorded during counts from 1970-1972 in the Kohala Mountain Forest, Hawaii. Numbers at the top in parentheses are sample sizes.

suggested that colonies of Manx Shearwater (*Puffinus puffinus newelli*) may exist in the Kohala Mountain Forest. The Kalij Pheasant (*Lophura leucomelana*) which has recently undergone a great range expansion on the island of Hawaii (Pratt 1975) has apparently not yet reached the Kohala Mountain Forest.

Uniformity of species composition.—In an effort to determine if bird species were uniformly distributed over widespread but similar areas in the Kohala Mountain Forest, comparative counts were undertaken. In all cases no significant difference in species composition existed between outlying areas and the principal study site (Eke: $\chi^2 = 3.54$, $df = 8$, $P = 0.90$; Kawainui Stream: $\chi^2 = 1.35$, $df = 6$, $P = 0.97$; Kehena Ditch Trail: $\chi^2 = 1.75$, $df = 6$, $P = 0.94$). These results suggest that bird species composition is relatively uniform over the extant Kohala Mountain Forest area.

Species abundance.—Overall numbers of most bird species in the Kohala Mountain Forest were higher than comparable studies reported from

TABLE 3
NUMBER OF ACTIVE NESTS FOUND FROM 1969-1972 ON KOHALA MOUNTAIN, HAWAII^a

Species	Months											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Amakihi	4	10	14	11	8	3	—	—	—	—	—	—
Apapane	—	1	3	4	2	—	—	—	—	—	—	—
Iiwi	—	2	5	4	1	—	—	—	—	—	—	—
Elepaio	—	1	1	2	6	4	3	1	—	—	—	—
Red-billed Leiothrix	—	—	—	1	3	3	1	—	—	—	—	—
Japanese White-eye	—	—	—	1	3	2	1	1	—	—	—	—
Nutmeg Mannikin	—	—	—	1	1	1	—	—	—	1	1	1
Common Mynah	—	—	2	4	3	—	—	—	—	—	—	—
Northern Cardinal	—	4	4	5	2	2	—	—	—	—	—	—
Eurasian Skylark	—	—	1	1	1	—	—	—	—	—	—	—
House Finch	—	—	—	1	4	10	7	—	—	—	—	—
House Sparrow	—	—	2	4	2	—	—	—	—	—	—	—

^a A nest can occupy more than a 1-month period.

Molokai (Scott et al. 1977) and Oahu (Shallenberger 1978), but lower than other forest areas on the island of Hawaii (Conant 1981b; Scott, pers. comm.). The intermediate numbers of birds recorded during this study may reflect the lowered carrying capacity of this small remnant of now nearly isolated forest. I found that the Apapane was the most abundant bird in the Kohala Mountain Forest, followed closely by the Japanese White-eye and then the Amakihi (Table 1). Not only was the Apapane the most abundant bird over the annual cycle, but it also had the most months when it had the highest relative abundance (Table 2). However, the Amakihi was the most consistently encountered species during count periods in the forest (species frequency = 0.98). The lower species frequency of the Iiwi was primarily a result of its absence during the nonbreeding censuses. However, even when present the Iiwi's relatively low species incidence value indicates that the bird was never commonly encountered.

I analyzed data from all counts conducted within the principal study area and found that numbers of Apapane, Amakihi, and Iiwi changed significantly over the annual cycle (analysis of variance; $P \leq 0.05$; Fig. 2). These three species are all nectarivorous, and their movements in and out of the study area might well be related to changes in local nectar availability as Baldwin (1953) showed was true for another 'ōhi'a forest on Hawaii. Of the non-nectarivorous species which were encountered frequently enough to determine if population movements occurred, none showed significant changes in the number of birds recorded/hour over the

TABLE 4
MEAN PERCENTAGE OF JUVENILE BIRDS RECORDED DURING 1115 H OF CENSUSING FROM
1970-1972 IN THE KOHALA MOUNTAIN FOREST, HAWAII

Species	Month (total hours censused)						
	January (172.5) ^a	February (150.5)	March (375.5)	April (79.0)	May (215.0)	July (101.0)	November (21.0)
Amakihi (701) ^b	2.0 (102) ^c	0 (67)	0 (59)	0 (11)	10.0 (31)	0 (8)	0 (2)
Apapane (1123)	7.0 (69)	3.0 (93)	0 (57)	14.0 (28)	59.0 (46)	87.0 (15)	7.0 (15)
Elepaio (332)	3.0 (36)	0 (36)	0 (42)	0 (9)	16.0 (25)	5.0 (20)	75.0 (4)
Iiwi (281)	53.0 (19)	0 (39)	0 (21)	29.0 (7)	50.0 (6)	100.0 (1)	0 (0)

^a Numbers in parenthesis = total hours censused.

^b Numbers in parenthesis = total birds counted.

^c Numbers in parenthesis = total visual observations each month.

annual cycle (analysis of variance; $P \geq 0.05$; Fig. 3). These birds tended to be either insectivorous (Elepaio) or omnivorous (Red-billed Leiothrix, Japanese White-eye).

Breeding seasons.—On Kohala Mountain, I found that the native birds tended to nest earlier in the year than did the introduced species (Table 3). The Amakihi showed a more contracted breeding period than has been reported for the population in the dry forest on Mauna Kea (Berger 1972, van Riper 1978b), but had a similar breeding period to the Amakihi from the wet forests of Kauai (Eddinger 1970) and Hawaii (Baldwin 1953). The Apapane and Iiwi had breeding periods similar to those reported from Kauai by Eddinger (1970). I found that the Elepaio had a slightly longer breeding season in the Kohala Mountain Forest than Eddinger (*in* Berger 1972) found for the bird on Kauai, and Conant (1977) found on Oahu.

The breeding seasons of all native species coincided well with immature birds observed during censuses (Table 4). Apapane juveniles were recorded over the longest period, but because it is not yet known the length of time that each of these species retain their juvenal plumage, the same birds may have been observed over an extended time period.

The introduced species on Kohala Mountain all exhibited breeding seasons similar to the limits set for each bird by previous workers. The Japanese White-eye breeding season was within the breeding period of an Oahu population (Guest 1973), but the Red-billed Leiothrix breeding period was later in the year than was given for this bird by Fisher and Baldwin

(1947). The dates of the Common Mynah nests that I found fell within the first third of the breeding season which Eddinger (1967) outlined for an Oahu population. All of the dates for House Finch nests that I located during this study occurred during the same months that other nests have been reported from Hawaii (van Riper 1976) and from Oahu (Hirai 1975). Breeding seasons for the other introduced birds from Kohala Mountain have not yet been determined in Hawaii.

MANAGEMENT RECOMMENDATIONS

Analysis of breeding and census data from the Kohala Mountain Forest shows that, while the present day avifauna is less diverse than historical records indicate, nine native species still exist on the mountain. Four species (Hawaiian Duck, Hawaiian Hawk, Hawaii Creeper, Nukupuu) identified during count periods are classified by the U.S. Fish and Wildlife Service as endangered (USDI 1966). Recent work on a number of endangered species in Hawaii has indicated that genetic fitness may be a problem in rarer species (Walker 1974; van Riper 1980; Temple, pers. comm.). It is therefore imperative that diverse gene pools be preserved in order to insure the genetic integrity of the extant species.

Although the forested area is much reduced in size, the remaining forest does fit a number of criteria Diamond and May (1976) deemed essential for a natural reserve. The forest is nearly circular in shape, which maximizes the area-to-perimeter ratio thus minimizing dispersal distances within the forest. A circular configuration also avoids a peninsular effect in which dispersal rate to outlying parts would be so low as to cause numerous local extinctions thereby diminishing the reserve's effective area. Secondly, the Kohala Mountain Forest has numerous easily accessible stepping stones of forest patches above Honokaa, which lead to the large pristine 'ōhi'a forest on the northeastern flank of Mauna Kea. Over time these forest patches would enable birds to emigrate into the Kohala Mountain Forest area. Finally, because of Hawaii's disharmonic fauna, many forest areas (of which Kohala is one) are well below the carrying capacities of similar-sized islands outlined by Diamond and May (1976) in their review of natural reserves.

The Kohala Mountain Forest area would therefore seem to lend itself well to the reintroduction of certain species which have been extirpated from this region. Translocations of avian species have been carried out quite successfully in New Zealand (Morris 1977, Best 1980), but other than with anatids, little attention has been given to this technique in Hawaii. The Hawaiian Thrush, which was once quite abundant (Perkins 1903) but has now been lost from the Kohala Mountain Forest, would seem to be a prime candidate for reintroduction. The bird still exists in high numbers

on the south and southeastern part of the island (van Riper and Scott 1979), and could be easily captured and transported to the Kohala Mountain Forest.

The Kohala Mountain Forest remains today one of the more inaccessible areas on the main Hawaiian Islands, and because of this can be preserved in its present condition. Barring the introduction of new avian predators, more successful competitors, or an epizootic, the area will remain a refuge for Hawaiian birds. Therefore, steps need to be taken to ensure the preservation of this small, but important native Hawaiian refugium.

SUMMARY

Censuses were conducted from 1970–1972 in the Kohala Mountain Forest, Hawaii. Native passerines were the most commonly encountered birds, with the nectar guild of the Drepanidinae having the greatest numbers of recorded individuals and being the most consistently detected birds. A number of species, known to have occurred historically in the forest, were not found during the study; however, four endangered species (Hawaiian Duck, Hawaiian Hawk, Hawaii Creeper, Nukupuu) were recorded during count periods. The Nukupuu has not been reported previously from the island of Hawaii.

Species composition was constant in the forest throughout the year. However, the nectarivorous species in the principal study area did undergo significant changes in numbers over the annual cycle. The number of non-nectarivorous birds recorded/hour of censusing did not change significantly in the principal study site over the annual cycle. Breeding periods, as determined from active nests and census data, were found to correspond somewhat closely with the presently known breeding season of each species in other areas of Hawaii.

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GEORGE MIKSCH SUTTON (1898–1982)

We are saddened to report the passing of Professor George Miksch Sutton at Norman, Oklahoma on 7 December 1982. Professor Sutton most generously endowed the color-plate fund of The Wilson Ornithological Society, was a former president of the Society and a former editor of The Wilson Bulletin.